THE ASESSMENT OF EQUILIBRIUM SENSE USING FORWARD TRANSLATION

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Abstract- **We reported the change of the center of pressure (COP) after forward platform translations in healthy subjects in other times. Therefore, the purpose of this research is to investigate the influence of individual differences for the COP and to confirm the reproducibility of the equilibrium tests with forward translation. These studies were performed on 14 healthy elderly subjects, who had a normal neurological examination and who had been examined the equilibrium tests about 3 months ago. Subjects stood barefoot on a three dimensional force plate on the platform, with feet parallel. The duration of the forward platform translations was 0.15 seconds, and the displacements were 3.75, 7.5, 10, 15, 20 and 30 mm. 6 trials were carried out at random. The COP data were recorded for 35 seconds during standing, and were analyzed for 5 seconds after translation. As to the reproducibility of the tests, the differences between 2 tests which were examined 3 months ago and which were examined this time were not significant. We also performed the nerve conduction studies (NCS) for the assessment of individual differences. The results were showed that the relationship between COP and NCS was not obvious.**
Keywords - **Aging, equilibrium tests, posture control**

I. INTRODUCTION

Displacement of the center of pressure (COP) on a platform has been measured and used as an index of postural stability in standing. In 1929, it was first reported by Basler [1] who measured displacement of the COP. In following studies, the effects of age, sex, and other factors were determined [2-3]. As posturography is one of the tests of equilibrium, the displacement of the COP increased as an effect of aging. Also the relationship between the displacement of the COP and the strength of muscles was reported [4]. With regard to the difference due to sex, the results of studies showed that the displacement of the COP for females was more unstable than males [2]. Moreover, in subsequent studies, corrective responses were observed by measurement of the COP with backward and forward platform translations and rotations [5-6]. Furthermore, there were many studies that measured electromyography (EMG) simultaneously in the lower limbs [7-8]. Besides being reported in normal subjects, measurements of the COP were carried out in a variety of patients such as: bilateral peripheral vestibular deficits, diabetic peripheral neuropathy, Parkinson's disease, and others [9-10]. Displacements of the COP were also measured to analyze the relationship between the stability of posture and falling.

It is important to predict or prevent falling in the elderly. The elderly suffer injuries and their bones may fracture in a fall, and it often takes a long time for a complete recovery. What makes it even worse is that the injuries by falls prevent an active social life for the elderly and these results in greater decline of body functions. Thereafter the elderly may fall again. However it is difficult to exclude the effects of aging on the value of displacement of the COP in the existing quiet-standing test. Shumway-Cook and colleagues [11] investigated the effects of two different types of cognitive tasks on stability, as measured by COP displacement, in young versus older adults with and without a history of falls. Two cognitive tasks, a sentence completion and a visual perceptual matching task, were used to produce changes in attention during quiet stance under flat versus compliant surface conditions. While no differences were found between the young adults and the older healthy adults on a firm surface without a task, when the task complexity was increased, significant differences in postural stability between the two groups became apparent. In contrast to the young and healthy older adults, postural stability in older adults with a history of falls was significantly affected by both cognitive tasks. We have been trying to predict the risk of falling by conducting a balance test with platform translation stimuli to point out the influence of aging and the differences in individuals that it is difficult to determine by means of posturography. As a first step, we investigated the change of the displacement of the COP after forward platform translation in normal subjects. We also recorded EMG from the lower limbs simultaneously to investigate the muscles used to maintain normal erect posture [12]. In this study, we performed this test again to make sure the reproducibility of it. In addition, we also performed NCS to examine the differences between individuals.

II. METHODOLOGY

1. Subjects

Fourteen (6 males and 8 females) normal elderly subjects (first exam 64.2 $\pm$ 3.49 yrs, second exam 65.1 $\pm$ 3.44, 159.5 $\pm$ 8.53 cm height, 59.0 $\pm$ 8.58 kg weight) with no history of neuromuscular disorders volunteered for this investigation. Each subject was fully informed about the possible risks and the nature of the experiment and each signed the informed consent. Neurological examination was normal and none had a Romberg sign.

2 Experimental design

Each subject stood barefoot on the three dimensional force plate on the platform, with feet parallel and gazed at a target, a circle 20 mm in diameter for thirty seconds. First, all subjects were measured at rest standing with eyes open and with eyes closed.

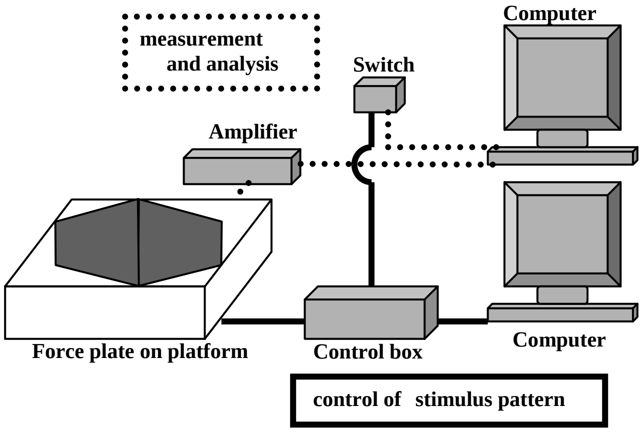


Fig.1 The experimental design

As to the forward platform translations, the time took 0.15 seconds, and the displacements were 3.75, 7.5, 10, 15, 20, and 30 mm for 0.15 seconds and recording were obtained over 30 seconds. The six trials were carried out at random, and the COP and EMG data were recorded during standing.

About 3 months later, we examined same trials for the subjects without recording EMG. In addition, we also performed NCS to examine the differences between individuals.

3. Apparatus and procedures

For COP recording, the three dimensional force plate on the platform (GS-6900B, Anima, Japan) was located in a well-lighted room (Figure 1). The device consisted of 2 computers and a force plate, control box, and switch for giving platform translation. The force plate was divided into 2 plates to calculate COP for each foot. One plate had three load cells that were located on an isosceles triangle. The data of COP were collected by the computer through an analog to digital convertor at 50 Hz.

For EMG recording, surface electrodes (NE-155A, NIHON KOHDEN CORPORATION, Japan) were secured to the skin over the belly of eight muscles (gluteus maximus, rectus femoris, biceps femoris, tibialis anterior, soleus, gastrocnemius, abductor hallucis, extensor digitorum brevis) of left leg by means of paste (Z-401CE, NIHON KOHDEN CORPORATION, Japan). The electrodes were discs, 11 mm in diameter, manufactured with Ag/AgCl. The EMG data were collected using a polygraph (DAE-2110, NIHON KOHDEN CORPORATION, Japan) at 1 kHz.

For NCS, we used the Evoked potential/Electromyogram recording device (Neuropack, NIHON KOHDEN CORPORATION, Japan). Motor nerve conduction velocity (MCV) of tibial nerve and peroneal nerve were measured in the lower extremities. Sensory nerve conduction velocity (SCV) of sural nerve was also measured in them. We adopted antidromic recording. The examinations were implemented in the shield room, where was kept 24 degrees C. One clinical technologist who has had good skill for NCS did all examinations because we hoped that there was little difference between subjects.

4. Data analysis

In the analysis of static COP recordings, we compared the data that were collected from normal subjects provided by the Company that produced the Device [13] with the data from the subjects in this study.

In dynamic trials, the COP data were analyzed from the data for 5 seconds after forward platform translations. The results of the COP were analyzed for the first 5 seconds after forward platform translations, since previous studies in disorders of posture control, e.g. patients with Parkinson's disease, showed most impressive changes at this time period (Unpublished data). We used the following in the analysis of the COP data in dynamic trials: the displacement length of the COP for x-direction (lateral), the displacement length of the COP for y-direction (anterior-posterior), maximum amplitude for x-direction, maximum amplitude for y-direction. We selected the indexes for y-direction, since the effects of translation stimuli for displacement of the COP were induced most remarkably by means of paying attention to the y-direction, i.e. anterior-posterior direction, as it was parallel with the direction of stimuli. We also selected the indexes for x-direction, since we thought the results of displacement of the COP for x-direction might be shown to compensate for the motion in the y-direction with stimuli exceeding some of the levels.

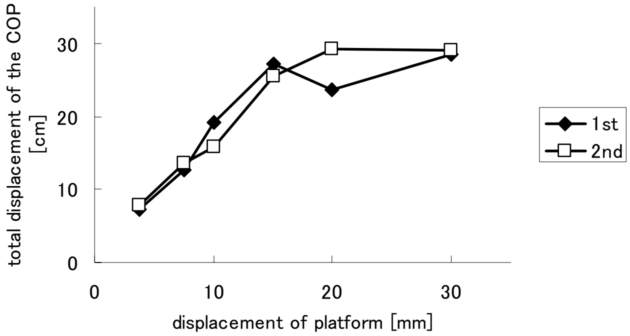
We judged that muscles that were more clearly activated, as observed by EMG recordings, during forward platform translations, than during quiet standings before translations, were "on", and those that were not clearly activated by EMG signal were "off"; i.e. if (maximum amplitude of EMG during translation) / (maximum amplitude of EMG before translation) > 1 was 'on', else 'off'. Significant differences between young and elderly groups were analyzed by Mann-Whitney's U test for the results of the COP, and by Fisher's exact probability test with raw EMG data.

III. Results

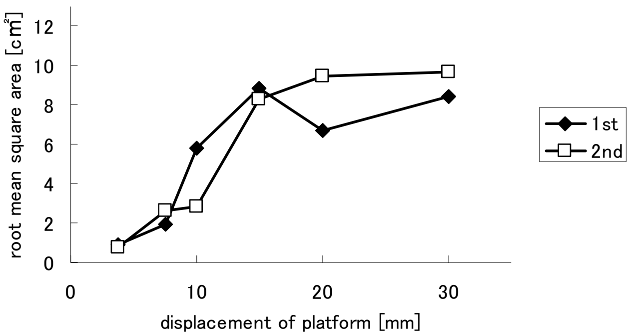
Figure 2 shows the mean values of displacement of the COP recorded for 5 seconds after forward platform translations; (a) total displacement, (b) root mean square area. The results showed no significant difference between two examinations to investigate the reproducibility of our equilibrium test.

Figure 3 shows the mean values of the displacement of the COP in individuals. There were differences in results of the COP among individuals. For verifying the individual differences, we examined nerve conduction studies (Table 1). Subject 14 was one of most influenced subjects by platform translations in the results of the COP, Subject 8 was one of least influenced. The results of NCS indicated no relationship between individual differences of the COP and the function of peripheral nerves.

Figure 4 shows the activities of muscles in foot region during the corrective responses with the platform translations. We are concerned here with muscle in foot region because abductor hallucis muscle and extensor digitorum brevis muscle are innervated muscles that we examined in NCS. In the results of Subject 8 and Subject 14, 0% means that the muscle indicates little activity, and 100% means that the



a) Total displacement



b) Root mean square area

Fig. 2 The mean values of displacement of the COP recorded for 5 seconds after forward platform translations

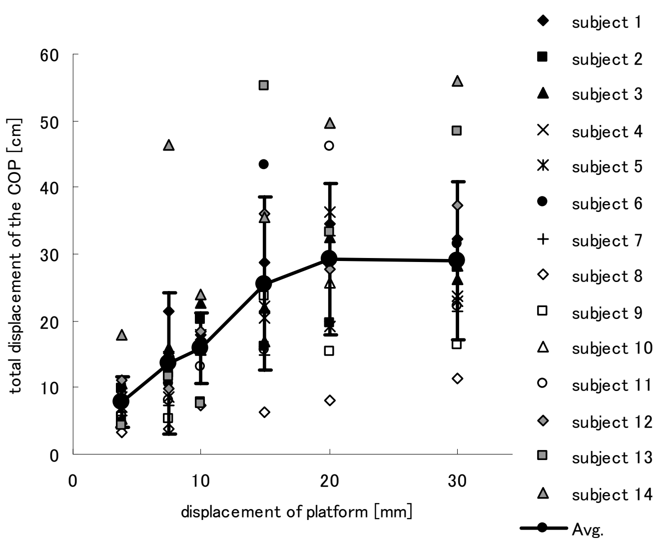


Fig. 3 The mean values of displacement of the COP recorded for 5 seconds after forward platform translations in individuals – Total displacement of the COP -

muscle indicates much activity. In the results of others (n=12), the ratio means the rate of number of those who indicates much activity of muscle. Subject 14, one of most influenced subjects by platform translations in the results of the COP, used muscles of foot region when he had been given small translation under examination. In contrast, Subject 8, least influenced subjects by platform translations in the results of the COP, used muscles of foot region only for large translations; 20mm and 30mm.

IV. DISCUSSION

The displacement of the COP has been measured as assessment of postural control. In addition to the measurement of the COP during quiet standing, corrective responses were observed by measurement of the COP with translation and rotation [5-6]. Our data [12] indicated that the displacement of the COP in platform translations from 3.75 to 15 mm showed a tendency to increase for y-direction (anterior-posterior). The results of the other stimuli between 20 and 30 mm varied greatly. In spite of greater intensity of the stimuli, the displacements of the COP didn't show a tendency to rise compared to that of 15 mm.

In this study, we examined same trials for the subjects without recording EMG after 3 months. The differences between 2 tests which were examined 3 months ago and which were examined this time were not significant. We think this result indicates the equilibrium tests suggested by us have the reproducibility. In addition, we also performed NCS to examine the differences between individuals. We indicated the results about the three types of subjects; one of most influenced subjects by platform translations in the results of the COP (Subject 14), one of least influenced (Subject 8) and others. The results of NCS indicated no relationship between individual differences of the COP and the function of peripheral nerves. Our subjects were healthy, so neurological examination was normal and none had a Romberg sign.

Therefore, we considered the results of EMG recordings. We are concerned here with abductor hallucis muscle and extensor digitorum brevis muscle. Subject 14, one of most influenced subjects by platform translations in the results of the COP, used muscles of foot region when he had been given small translation under examination. In contrast, Subject 8, least influenced subjects by platform translations in the results of the COP, used muscles of foot region only for large translations; 20mm and 30mm.

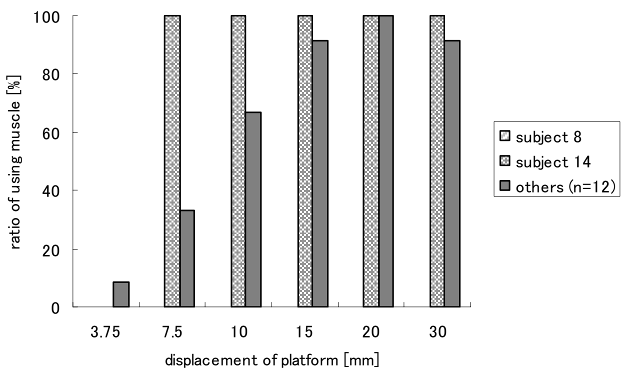
As to the subject that seldom use the muscles of foot region, the increase in activation of lower limb muscles such as tibialis anterior, soleus and gastrocnemius occurred according to the intensity of the stimuli in small stimuli. We think that these results indicate that ankle synergy stabilizes the erect body. In other words, it may be possible to estimate the individual's ability to make corrective responses by ankle synergy from the study of short platform translations. Furthermore, the results suggest the possibility of devising an index of the ability of posture control from the effect of the range of motion (ROM) for the ankle and aging by means of this type of testing.

The differences about how to use the muscles of foot region provided some insight into posture control. As to the subject that used the muscles of foot region with short stimuli, activation of proximal muscles such as the gluteus maximus and biceps femoris increased. However the increase of displacement of the COP was not so remarkable except for

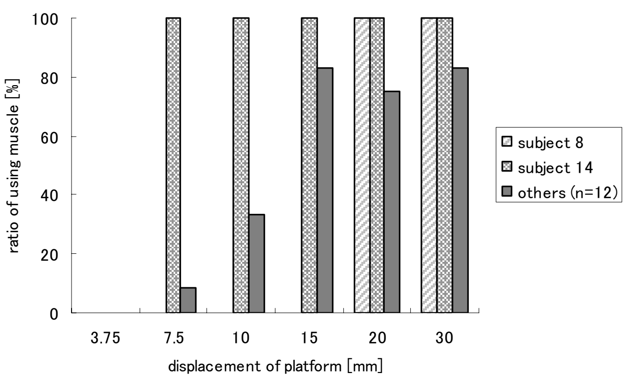
Table 2 The results of nerve conduction studies (NCS)

Subject No.		Left			Right		
		MCV		SCV	MCV		SCV
		tibial n.	peroneal n.	sural n.	tibial n.	peroneal n.	sural n.
8		48.8	46.9	55.1	54.9	47.8	48.8
14		49.0	46.3	51.3	44.7	47.8	50.8
others (n=12)	Avg.	46.3	47.9	52.9	46.8	46.2	53.6
	SD	3.53	1.26	5.37	6.69	5.12	3.74

[m/s]



a) Abductor hallucis muscle



b) Extensor digitorum brevis muscle

Fig. 4 The activities of muscles in foot region during the corrective responses with the platform translations.

3.75mm. These results suggest that hip synergy and/or the ankle synergy stabilize the body in individuals. In these cases, therefore, we think that postural control was multi-segmental, and the results were influenced by individual differences. Some of the factors that may produce the individual differences may be muscle volumes, muscle strength, ROM and others.

V. CONCLUSION

In conclusion, this study suggests that the individual's ability to control posture can be assessed by measuring the displacement of the COP after platform translation. This study also suggests that this may be helpful in understanding how synergies work. Furthermore the testing in this study is safe and without pain. We anticipate that this type of testing will be useful in the evaluation of postural control in the elderly.

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